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Deformation Mechanisms in Mg-Al Nanocomposite

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Introduction

Magnesium is the lightest engineering metal [1]. Replacing steel with Mg-based materials in automotive applications would lead to more than 40% weight reduction which significantly boost fuel efficiency [2]. However, conventional Mg alloys typically suffer from low strength and poor deformability due to very few slip systems and easy twinning [3].

Alloying Mg with other materials and microstructural engineering are promising approaches to increase ductility and strength of Mg. According to Wang et al. [4], interfaces with low energy and high coherency may effectively constrict the nucleation of twins in Mg. In this work, the microstructure of Mg nano-layers and nano-rods were examined after deformation to determine the dominant deformation mechanisms.

Methods

- ✓ Mg-Al nanocomposites with eutectic composition (33 wt.% Al) were produced by arc melting and melt spinning and analyzed by X-Ray Diffraction to validate presence of the desired phases.
- ✓ Micropillars made in dual-beam FEI Helios Nano-lab 660 equipped with Ga Focused Ion Beam (FIB)
- ✓ In-situ compression test using PI 85L SEM Picoindenter
- ✓ Nanoindentation test performed at Hysitron TI 950 Triboindenter applying 8000 μN force on Mg-Al arc melted ingot.
- ✓ Transmission Electron Microscopy (TEM) lift-out samples prepared by FIB milling technique
- ✓ Conventional BF TEM and HRTEM conducted in FEI Tecnai Osiris at 200kV.

In-situ Compression Test

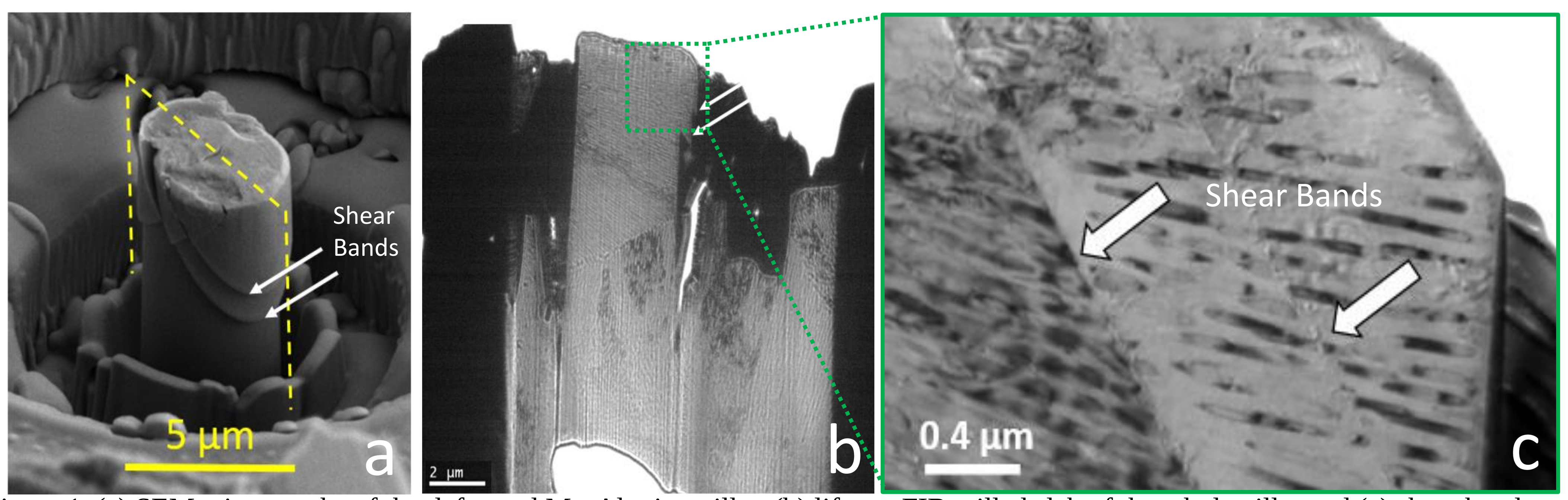

Figure 1. (a) SEM micrographs of the deformed Mg-Al micropillar, (b) lift-out FIB milled slab of the whole pillar and (c) shear bands.

- ❖ The Mg-Al nanocomposite micropillar after the in-situ microcompression shows shear bands (Fig.1a).
- ❖ A thin slice of the deformed micropillar were prepared by FIB milling technique (Fig. 1b and 1c).
- ❖ The high resolution TEM (HRTEM) images (Fig. 2a and 2b) illustrate pyramidal dislocations frequently occurred througout the Mg rods next to the shear bands.
- ❖ Fig. 3c depicts the only trace of twins found in our investigation.

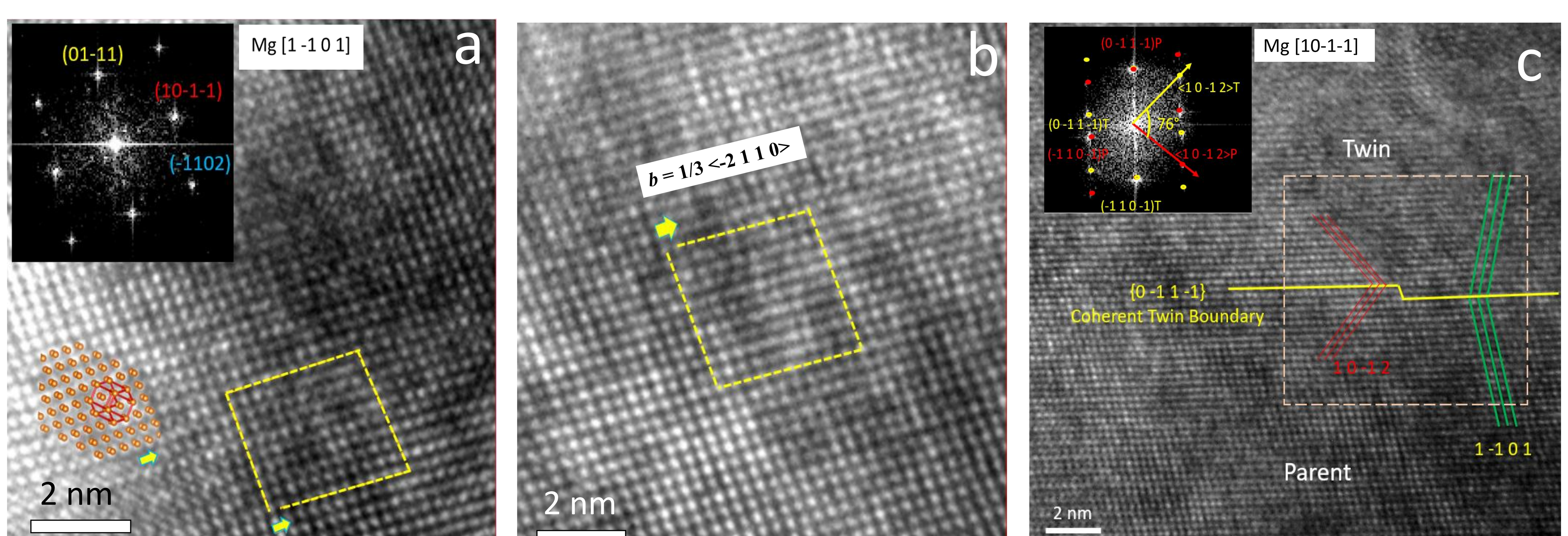

Figure 2. HRTEM images of deformed Mg fibors indicating pyramidal dislocations (a and b) and a compression twin (c).

Nanoindentation

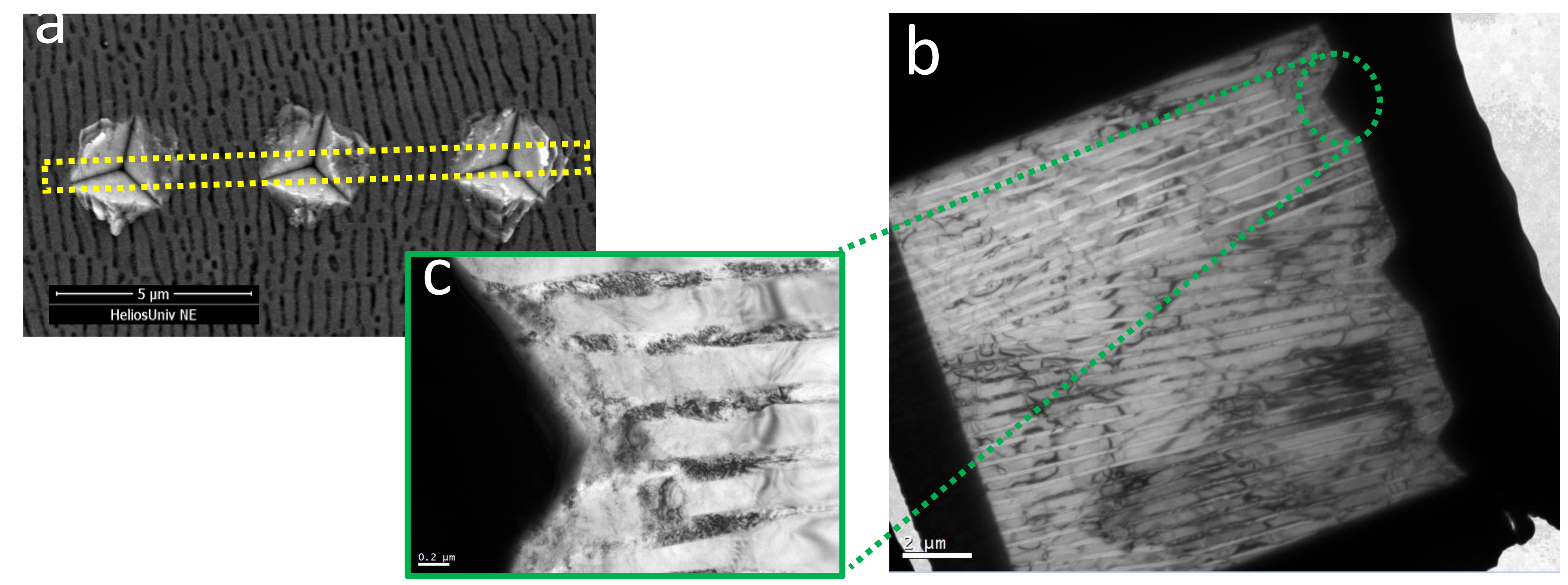

Figure 3. (a) SEM micrograph of nanoindentations, (b) Lift-out FIB milled slab of region confined in dash rectangular in (a), and (c) deformed area around an indent.

- ❖ The selected area of the indents to fabricate a cross-sectional lift-out thin slab by FIB milling is illustrated in Fig. 3a.
- ❖ Piling up is evident in Fig. 3a and depending the orientation of the Mg layers, there exist shearing and plastic deformation.
- ❖ HRTEM of the layers far from indentation shows a defect free microstructure (Fig. 4).
- ❖ Pyramidal and prismatic dislocations were detected in the deformed region close to the indentation (Fig. 5). The crucial point is twinning rarely observed. More investigation is being doing to elucidate the dominant deformation mechanism in these areas.

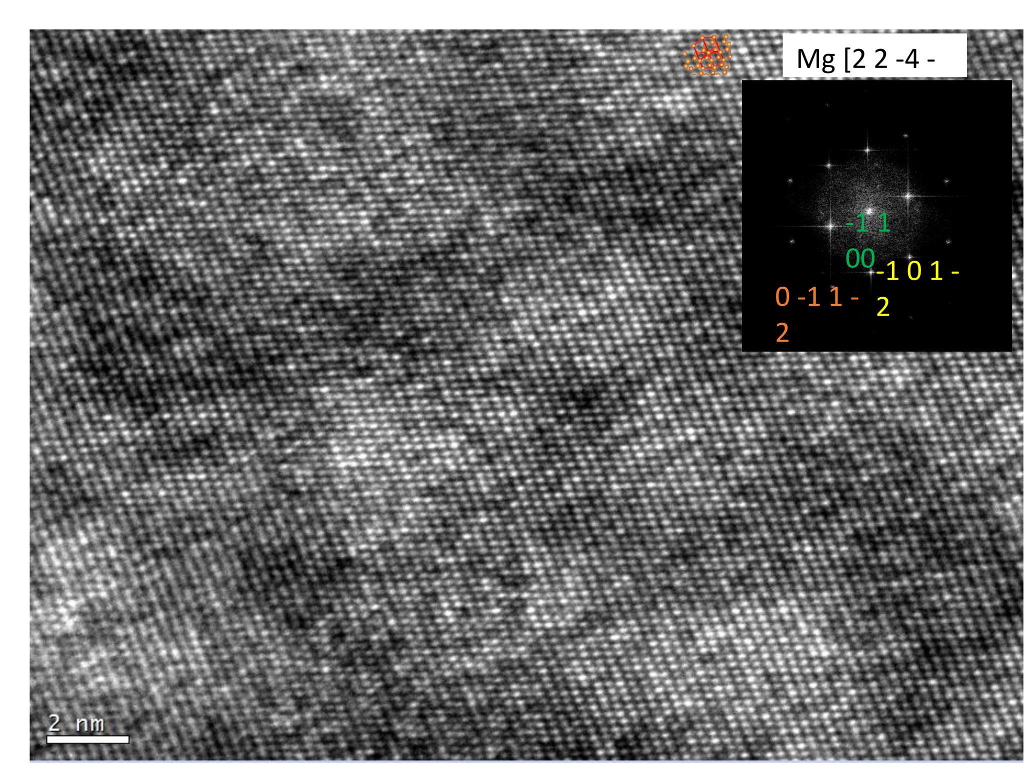

Figure 4. HRTEM image of the undeformed Mg layer far from the indentation (the inset is inverse FFT of the region confined by the green dash line)

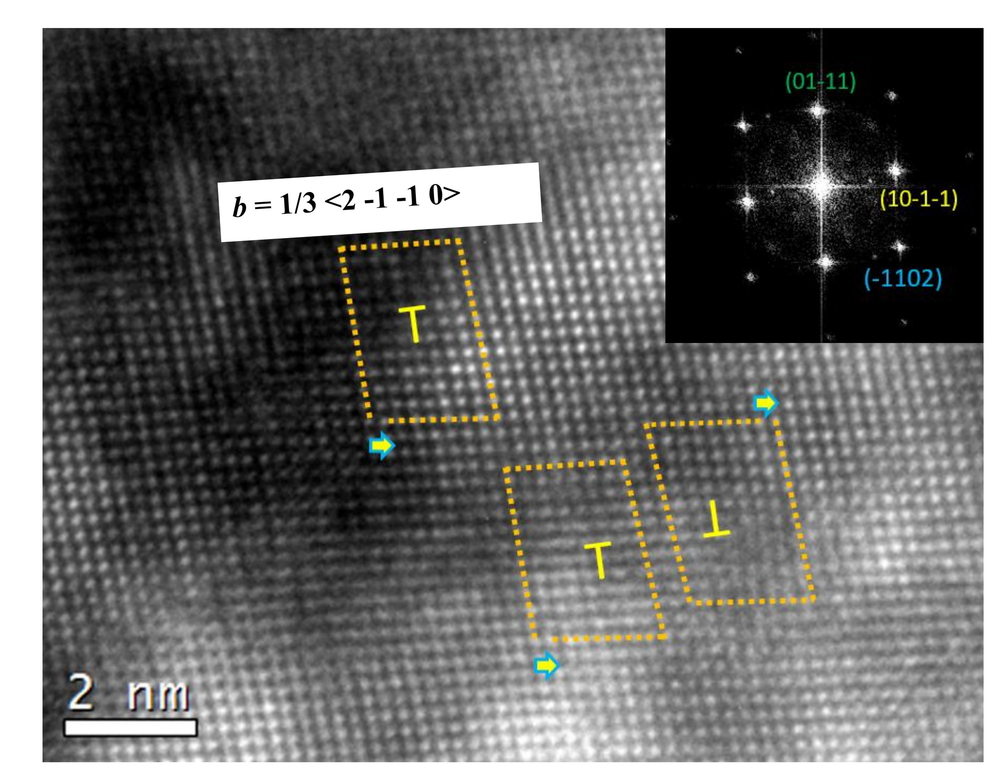

Figure 5. HRTEM of deformed area indicating pyramidal dislocations.

Conclusion

MgAl nanocomposites deformed by microcompression and nanoindentation methods were evaluated by HRTEM and it was found that edge dislocations as well as the stacking faults played the main role in accommodation of the strains in Mg nano-layers and nano-rods. This work have shown that twinning was effectively suppressed in the nano-scale Mg features.

Acknowledgement

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